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Minimum Wage and Employment

Sectoral and Regional Perspectives

Yan Chen and Jiaxiong Yao

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Minimum Wage and Employment: Sectoral and Regional Perspectives

Prepared by Yan Chen and Jiaxiong Yao*

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ABSTRACT: Most European countries have a single national minimum wage. An increase in minimum wage implies shocks of different magnitudes to sectors and subnational regions. Using sectoral and regional variations of minimum wage to average wage ratios in European countries, we estimate the dynamic and heterogeneous treatment effects of minimum wage changes on employment through local projections and generalized random forests. We find that the average employment effects of minimum wage increases tend to be negligible in the short term but negative in the medium to long term. The employment effects are heterogeneous in gender, age, the size of the minimum wage increase, and the minimum wage to average wage ratio. Minimum wage increases appear to have a threshold effect on employment at the sectoral level. The employment effects become negative when the minimum wage is above 35 percent of the sectoral average wage.

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Author's E-Mail Address:	ychen8@imf.org; jyao@imf.org

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I. Introduction

One of the most contentious labor market policy debates is on the impact of minimum wage increases on employment. To date, it is still inconclusive.

Empirically, earlier literature has suggested a negative impact, but recent findings have pointed to neutral or even positive impact (Wolfson and Belman, 2019). Theoretically, the impact could be in both directions. While textbook analysis points to negative employment effects of a binding minimum wage in a perfectly competitive labor market, the existence of monopsony power and non-employment margins means that minimum wage increases do not necessarily jeopardize employment (Azar and Marinescu, 2024; Clemens, 2021). Meanwhile, evidence of the impact on overall employment is scant, as the literature tends to focus on those most affected by minimum wage increases, such as teens and low-wage workers (Cengiz and others, 2019).

In this paper, we analyze the employment effects of minimum wage changes in European countries. One crucial fact that we exploit is that most European countries have a single national minimum wage. This implies that the degree to which it is binding for firms differs across sectors and subnational regions. As such, the same increase in a national minimum wage would have different labor cost implications at disaggregated levels. Using variations in minimum wage to average wage ratios across sectors and regions, we estimate the dynamic and heterogeneous treatment effects of minimum wage changes on employment.

The sectoral and regional analyses are complementary to each other. Typically, the average wage differs more substantially across sectors than across subnational regions in a country, the minimum wage to average wage ratio therefore has more variations across sectors. Moreover, sectoral labor costs are usually tracked at the quarterly frequency, whereas regional labor costs are measured annually. The sectoral level data are thus of higher frequency and more suitable for short-term analysis. However, at the sectoral level, there is no well-defined concept of population, labor force, or unemployment. In contrast, subnational regions have such concepts, allowing us to examine various margins of adjustment of the employment effects of minimum wage increases.

The treatment variable in our analysis is the change in the minimum wage relative to the average wage in the previous period. Since the European countries covered in this paper each have a single national minimum wage, minimum wage increases reflect economic developments and political considerations at the national level. Idiosyncratic labor market developments at the sectoral or regional level should have limited impact on decision

making at the national level. The endogeneity issue is thus less of a concern. Minimum wage increases, however, could have a nonlinear impact on employment. In particular, it is likely that a small increase in the minimum wage has a negligible impact on employment while a large one has a significant impact. In light of this, we also consider a discrete version of the treatment variable that captures only large minimum wage increases.

While the minimum wage is often adjusted annually or semiannually, the average wage at the sectoral level or the regional level is surveyed only every four years. To overcome the infrequent availability of wage data, we perform imputations of average wages using the more frequently measured labor cost index at the sectoral level and national accounts compensation per employee by subnational regions.

We use two well established empirical methods to analyze the employment effects of minimum wage increases. First, we use the local projections method (Jordà, 2005; Jordà and Taylor, forthcoming) to estimate the dynamic effects of minimum wage increases on employment. This provides us with a temporal perspective of the average treatment effect of minimum wage increases. Next, we explore the heterogeneity in such effects—both in the short term and long term—using a machine learning tool, the generalized random forest (Athey, Tibshirani, and Wager, 2019). This gives us a cross-sectional perspective of the heterogeneous treatment effects across various minimum wage to average wage ratios.

Our main findings are threefold. First, we find that the average employment effects of minimum wage increases tend to be negligible in the short term but negative in the medium to long term. Our sectoral analysis shows that the average treatment effect on employment rate is near zero within one year but becomes negative afterward. Complementary to such a result, our regional analysis further shows that the negative employment effects tend to peak in the thrid or fourth year, and they are driven by the decline in the labor participation rate.

Second, the employment effects of minimum wage increases are heterogeneous in gender, age, the size of the minimum wage increase, and the minimum wage to average wage ratio. At the sectoral level, minimum wage increases tend to boost young employment, mostly benefiting young men. Differentiating positive and negative real minimum wage changes, we show that when the minimum wage increases more than inflation, it boosts employment rates for the young in the short term, but when it remains unchanged or increases less by inflation, inflation gradually eases the bindingness of the minimum wage and employment rates rise in the medium term.

Large minimum wage increases reduce employment rates in the long term, with more detrimental effects on women. The employment effects are more negative for sectors

where the minimum wage to average wage ratio is higher. Such heterogeneous impact manifests itself over time, becoming significant after two years. It also cuts across various sub-population groups, including males, females, and the young.

At the regional level, minimum wage increases reduce employment rates. This is primarily driven by the decline in labor force participation rates. However, minimum wage increases appear to reduce the employment rate for the young initially but increase it in the long term. We show that net migration follows a similar pattern and might play a role in driving such dynamics.

Third, minimum wage increases appear to have a threshold effect on employment. Our generalized random forests method shows that at the sectoral level, when the minimum wage to average wage ratio is below 35 percent, large minimum wage increases have little impact on employment both in the short term and in the long term. However, when it is above 35 percent, the employment effects become negative both, particularly in the long term. At the regional level, there does not appear to be a threshold. However, the long-term employment effects are mostly negative.

A brief review of related literature

The literature on the employment effects of minimum wage is vast. We provide a brief and certainly non-exhaustive review of several strands of the recent literature that are closely related to this paper.

The standard elementary textbook treatment of minimum wage views its impact on employment as unambiguously negative (Flinn, 2011): a minimum wage greater than the market-clearing wage reduces employment in a perfectly competitive labor market. However, the magnitude of employment effects is controversial. Although earlier literature has found an elasticity of teenage employment to minimum wage between -0.3 and -0.1 (Brown, 1988; Mankiw, 2013), recent evidence has pointed to a much smaller negative impact (Wolfson and Belman, 2019). Most of the literature focuses on the quantification of short-term impact in the United States. This paper adds sectoral and regional perspectives from European countries, quantifying the employment effects both in the short term and long term.

Beyond the standard textbook analyses, a number of factors affect the employment effects of minimum wage, including monopsony power (Azar and Marinescu, 2024), local economic conditions (Dube, Lester, and Reich, 2010), migration (Simon and Wilson, 2021; Strobl and Walsh, 2016), informality (Pérez, 2020; Samutpradit, 2024), non-compliance (Badaoui and Walsh, 2022), substitution toward more productive workers

(Horton, 2025), output prices and non-wage aspects of jobs (Clemens, 2021). Some factors, such as monopsony power, mitigate the negative employment effects of minimum wage (Azar and others, 2024). Other factors, such as local economic conditions and informality, could have ambiguous impact. It is therefore an empirical question what the overall impact is at the sectoral level and the regional level, a question that this paper seeks to answer. In addition, we highlight another factor that is important for the employment effects, the minimum wage to the average wage ratio, which indicates the degree of bindingness and is therefore an important source of heterogeneity for the employment effects.

An emerging literature focuses on the minimum wage setting at the national level. Simon and Wilson (2021) analyzes the optimal wage setting in a federal system, highlighting that decentralized minimum wage setting exerts horizontal migration externalities, whereby an increase in the minimum wage reduces the wage of high-skilled workers and drives their migration. Dustmann and others (2022) find no negative employment effect of the introduction of Germany's first national minimum wage, and show that the German labor market absorbed the wage increase not through job losses, but by reallocating low-wage workers from smaller, lower-paying, and less productive firms to larger, higher-paying, and more productive ones. The positive reallocation effects they find are not mutually exclusive with the net negative employment effects in our paper. It is possible that while many workers "trade up" to better firms, the exit of the least productive firms is not fully offset by the expansion of more productive ones, leading to a small net job loss over the medium term. Ahlfeldt, Roth, and Seidel (2022) develop a quantitative spatial model with heterogeneous firms and a monopsonistic labor market to derive minimum wages that maximize employment in Germany. They find that employment-maximizing should be set at 50% of the regional mean wage. Closely related to this, our generalized random forests analysis shows that the employment effects of minimum wage become negative when the minimum wage exceeds 35% of the sectoral average wage. Giupponi and others (2024) exploit geographical variation in the level of wages in the United Kingdom to assess the impact of nationwide minimum wages on employment throughout the whole wage distribution. This is similar to our regional perspective. However, this paper extends the country coverage and also exploits variations of average wages at the sectoral level.

Analyzing the employment effects of minimum wage with machine learning is still new in the literature. Cengiz and others (2022) use a few machine learning tools to estimate the impact of minimum wages on labor market outcomes and find that the employment impact is small, positive, yet statistically insignificant while changes in the unemployment rates or labor force participation rates are not substantial. While their focus is on using a prediction model to classify workers who are likely to be exposed to a minimum wage treatment, the focus of this paper is different. We use generalized random forests to

estimate individual treatment effect, which could be zero even for those exposed to the minimum wage and non-zero for those not directly exposed.

The rest of the paper is structured as follows. Section II describes the two empirical approaches used in this paper. Section III discusses the data and some stylized facts about minimum wage, average wage, and employment rates. Section IV explains the empirical findings at the sectoral level and the regional level and draws policy implications. Section V concludes.

II. Empirical Framework

In this section, we present two empirical approaches. First, we use the local projections method to estimate the dynamic effects of minimum wage increases on employment. Next, we explore the heterogeneity in such effects using generalized random forests (Athey, Tibshirani, and Wager, 2019).

Our identification strategy leverages the institutional feature that most European countries have a single national minimum wage. A uniform national minimum wage increase acts as a national-level shock. However, its intensity varies across different sectors and subnational regions due to differences in their average wage levels. We exploit this cross-sectional variation in the treatment intensity, measured as the change in the national minimum wage relative to the lagged average wage in a given sector or region.

The key identification assumption is that the national-level decision to change the minimum wage is exogenous to the idiosyncratic economic shocks affecting any single sector or region. In most European countries, the minimum wage is determined through a collective bargaining process, influenced by national developments such as average cost of living, average wage growth, and inflation. While the national minimum wage may respond to the national economic development, it is unlikely to be dictated by the concurrent employment trend in, for example, the manufacturing sector of a country or the labor market conditions of a single subnational region. Since the national economic development is the aggregation of sectoral and regional economic developments, it reflects national shocks, whereas the idiosyncratic components of local shocks tend to average out. As such the change in the national minimum wage can be viewed as exogenous to sectoral and regional employment developments. Using this "treatment intensity" design and controlling for a rich set of fixed effects and trends, we can isolate the causal impact of minimum wage changes on employment outcomes.

A. Local Projections

We follow the canonical local projections setting in Jordà (2005) and specify the regression equation as follows,

$$y_{c,i,t+h} - y_{c,i,t-1} = \tau^h w_{c,i,t} + \sum_{k=1}^{p} (\beta_k^h X_{c,i,t-k} + \gamma_k^h \Delta y_{c,i,t-k}) + \eta_{c,t+h} + \zeta_{c,i} + \varepsilon_{c,i,t+h}, \quad h = 0, 1, 2, ... \tag{1}$$

where the subscript c indicates a country, i a sector or a subnational region, and t time. $y_{c,i,t}$ is the variable of interest for country c, sector (or region) i, and time t, which could be employment, activity rate, unemployment, or hours worked. We use a long difference specification on the left-hand side, which could reduce small sample biases (Jordà and Taylor, forthcoming).

$w_{c,i,t}$ is the treatment variable, defined as follows:

$$w_{c,i,t} = \frac{\frac{MW_{c,t}}{P_{c,t}} - \frac{MW_{c,t-1}}{P_{c,t-1}}}{\frac{W_{c,i,t-1}}{P_{c,t-1}}} = \frac{MW_{c,t} - MW_{c,t-1}(1+\pi_{c,t})}{W_{c,i,t-1}(1+\pi_{c,t})}, \tag{2}$$

where $MW_{c,t}$ is the minimum wage of country c at time t and $P_{c,t}$ is the price level. $W_{c,i,t-1}$ is the average wage, which differs across sectors and regions. $\pi_{c,t}$ is inflation. $w_{c,i,t}$ is therefore the real minimum wage change relative to the average wage.[1]

The key insight in this treatment variable is that a single national minimum wage implies different relative labor costs in each sector and each region. The same increase in the nominal minimum wage means labor cost shocks of different magnitudes across sectors and regions. Moreover, this treatment variable allows us to examine both positive and negative changes of the ratio $w_{c,i,t}$ and their impact on employment. When the minimum wage increase exceeds inflation, $w_{c,i,t} > 0$ and the bindingness of the minimum wage would increase; when the minimum wage is eroded by inflation, $w_{c,i,t} < 0$ and the bindingness of the minimum wage would loosen.

We also consider a discrete version of the relative minimum wage changes, because its impact on employment could be nonlinear. In particular, small minimum wage increases may not have the same impact as large minimum increases. We define a large minimum wage increase as one that is above the 90th percentile of the relative minimum wage increase in the data:

$$I_{c,i,t} = \begin{cases} 1 & \text{if } w_{c,i,t} > p_w^{90}, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

[1] Minimum wage increases are backward indexed to varying degree across European countries. Taking inflation into account therefore makes minimum wage changes more comparable across countries.

X is a set of control variables that include lags of real minimum wage changes relative to the average wage. The number of lags p is chosen by the Akaike Information Criterion. $\eta_{c,t}$ is the country-by-time fixed effect that captures country-specific time trends and ζ_{ci} time-invariant factors at the country-industry level for the sectoral data or at the country-regional level for the regional data. $\varepsilon_{c,i,t}$ is the error term.

B. Generalized Random Forests

Equation (1) is a linear model, where τ^h measures the average treatment effect at horizon h of a minimum wage increase. Such a specification could mask important heterogeneity. In particular, the employment effect of minimum wage changes could depend on where the minimum wage is at compared to the average wage. If the minimum wage is low, an increase could reduce the monopsony power of firms and boost employment. On the other hand, if the minimum wage is high and binding for many firms, an increase could weaken labor demand and reduce employment.

To investigate the heterogeneity of the employment effects of minimum wage increase, we use the method of generalized random forests (Athey, Tibshirani, and Wager, 2019). Generalized random forests is a machine learning method that estimates heterogeneous treatment effects by partitioning the data into groups with similar characteristics and estimating the effects within each group. This helps in identifying thresholds or nonlinearities, such as whether the effect turns negative when the minimum wage is already high relative to average wages. We consider the following regression:

$$\begin{aligned} y_{c,i,t+h} - y_{c,i,t-1} &= \tau^h\left(X_{c,i,t-1}\right) I_{c,i,t} \\ &+ \sum_{k=1}^{p} \left(\beta_k^h X_{c,i,t-k} + \gamma_k^h \Delta y_{c,i,t-k}\right) + \eta_{c,t+h} + \zeta_{c,i} + \varepsilon_{c,i,t+h}, \quad h = 0,1,2,... \end{aligned} \tag{4}$$

Equation (4) is identical to equation (1) except for the first term on the right hand side. $I_{c,i,t}$ is an indicator that equals 1 if there is a large minimum wage increase in country c at time t and 0 otherwise, as in equation (3). Note that when the minimum wage is national, it does not depend on i. $\tau^h(X_{c,i,t-1})$ is the average treatment effect at horizon h that depends on the characteristics of a sector or a region. One specific characteristics that we explore is the minimum wage to average wage ratio in the period before the minimum wage increase.

Generalized random forests is a method for nonparametric estimation. In our setting, the average treatment effect $\tau^h(\cdot)$ is a nonparametric function. This allows us to examine the nonlinear relationship between the treatment effect and the minimum wage to average wage ratio. A special case is the threshold model (Card, Mas, and Rothstein, 2008; Hansen, 1999), where $\tau^h(\cdot)$ is piecewise linear and the threshold(s) is estimated from data.

Generalized random forests extends random forests, a widely popular statistical learning algorithm (Breiman, 2001). From a statistics perspective, random forests can be used as a method for nonparametric estimation of the conditional mean $E(y|X)$, and generalized random forests generalizes it to a method that can estimate any quantity $\tau^h(X)$ identified via local moment conditions, including conditional means, quantiles, etc.

In our setting, generalized random forests finds an adaptive nearest neighborhood of $X = x$ where the treatment effect $\tau^h(x)$ is constant and runs a weighted residual-on-residual regression (Robinson, 1988) to estimate it. Generalized random forests estimates are consistent and asymptotically Gaussian, and confidence intervals can be constructed from estimated asymptotic variance (Athey, Tibshirani, and Wager, 2019).

In practice, we focus on $\tau^h(\omega_{c,i,t-1})$ and take a two-step approach to estimate it. First, we remove the fixed effects in employment growth in equation (4) by regressing employment growth on country-by-time fixed effects and country-industry (or country-region) fixed effects and obtaining the residual. Second, we conduct a generalized random forests estimation of the heterogeneous treatment effects using the residual from the first step:

$$\begin{aligned} \widehat{\Delta y^h_{c,i,t-1}} &= \tau^h\left(X_{c,i,t-1}\right) I_{c,i,t} \\ &+ \sum_{k=1}^{p} \left(\beta^h_k X_{c,i,t-k} + \gamma^h_k \Delta y_{c,i,t-k}\right) + \varepsilon_{c,i,t+h}, \quad h = 0,1,2,... \end{aligned} \tag{5}$$

where $\widehat{\Delta y^h_{c,i,t-1}}$ is $y_{c,i,t+h} - y_{c,i,t-1}$ removed of fixed effects.

III. Data and Stylized Facts

In this section, we construct two panel datasets. One dataset focuses on sectors, with the unit of observation being a country-sector at a point in time. The other focuses on regions, with the unit of observation being a country-region at a point in time.[2]

The sectoral panel dataset has better country coverage and higher frequency, as most European countries have readily available data on average wage, employment, and hours worked at the detailed sectoral level and quarterly frequency. The benefit of this dataset is that it has many observations and rich variations in the minimum wage to average wage ratio. The regional panel dataset is limited, because data are at the annual frequency and often incomplete, but it has a key advantage that there are labor force and unemployment concepts at the regional level, which allows us to examine different margins of employment adjustments in response to minimum wage increases.

Our primary data source is Eurostat. For the sectoral panel dataset, we focus on 31 European countries[3] between 2008-Q1 and 2024-Q2 for which minimum wage and sectoral level (NACE Rev. 2) labor market information are available. Overall, the panel data contain 485 country-industry pairs and 66 quarters between 2008-Q1 and 2024-Q2. The panel is unbalanced as for some countries, labor market information is incomplete at the beginning of the sample or during the pandemic.

For the regional panel dataset, we have 28 European countries and 246 NUTS-2 regions between 2008 and 2022. The panel is unbalanced as different labor market information is incomplete to varying degrees. This level of aggregation may mask significant heterogeneity within regions, for example, a single NUTS-2 region can contain both a dense urban labor market with many employers and rural areas with far fewer employers, and therefore, a single national minimum wage could have very different effects in a more competitive urban market than in a monopsonistic market, even within the same NUTS-2 region. However, our paper provides an average effect at the sectoral and regional level across Europe, while future country-specific research could explore these finer intra-regional dynamics with more granular data.

[2] Since the labor market varies locally and across sectors, a panel dataset at the most disaggregated local and industry levels would be ideal. However, given the data limitations, we resort to constructing two separate datasets. Finer intra-regional and industrial dynamics could be explored with more granular data.

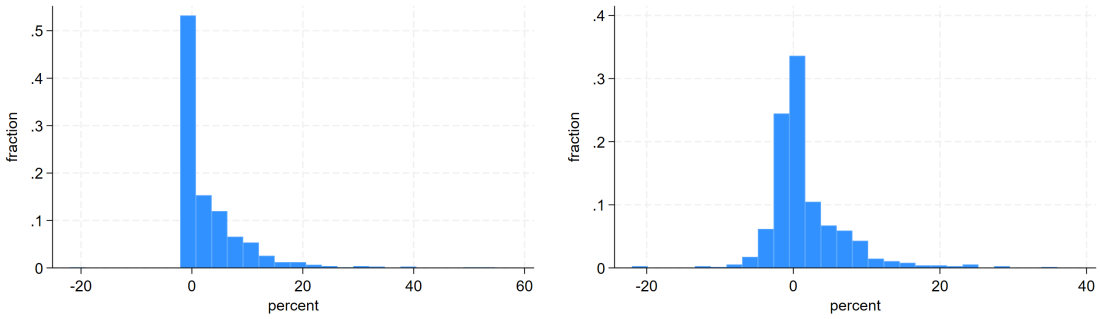
[3] They include all 27 European Union countries as well as Iceland, Norway, Serbia, and Türkiye.

A. Minimum wage

Countries adjust minimum wage in their domestic currency either semi-annually or annually. Eurostat provides data on minimum wage at semi-annual frequency. Of the 31 countries in the sectoral panel, 20 countries have minimum wage at the beginning of the sample (2008-Q1), 7 countries have no minimum wage throughout the sample, and 4 countries introduced minimum wage in the middle of the sample.

Figure 1 and Table 1 present the distribution of half-yearly percent changes in the minimum wage in our sectoral panel. At half-yearly frequency, over 50 percent of the time the nominal minimum wage stays the same as before. Nominal minimum wage decreases are rare. There is only one large decrease in 2012 when Greece cut the minimum wage by 22 percent during the Euro debt crisis. A nominal minimum wage increase of 10 percent is roughly at the 90th percentile of all minimum wage increases. Exceptionally large minimum wage increases usually occur during high inflation episodes, such as during 2022-2024 in Türkiye.

Figure 1. Distribution of Half-yearly Minimum Wage Changes



(a) nominal changes **(b) real changes**

Sources: Eurostat and IMF staff calculations.

Table 1. Summary Statistics of Half-Yearly Minimum Wage Changes

	Mean	Std	Min	p5	p10	p25	p50	p75	p90	p95	Max
nominal change	3.5	6.3	-22.0	0.0	0.0	0.0	0.0	5.0	10.3	14.8	54.7
real change	1.6	5.2	-22.0	-3.9	-2.6	-0.9	0.3	3.0	7.9	11.1	36.0

Sources: Eurostat and IMF staff calculations.

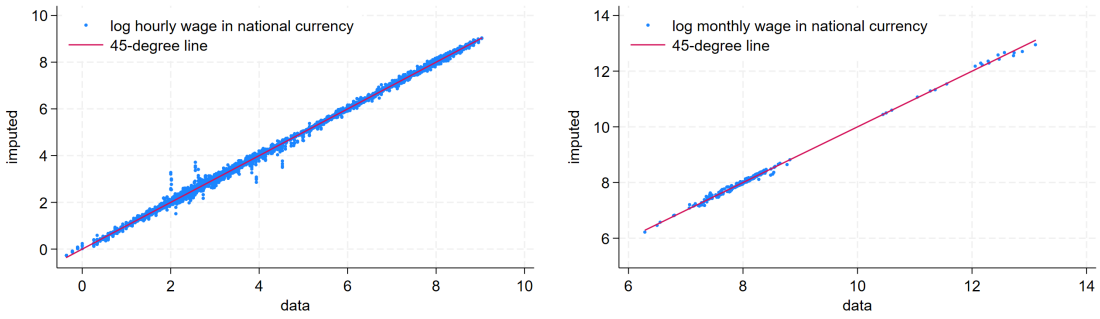
B. Average wage

The average wage is measured infrequently at the sectoral level or the regional level. The Structure of Earnings Survey (SES) has average hourly wage data, covering all economic activities defined in NACE Rev. 2 sections B to S. The Labour Cost Survey (LCS) provides detailed information on the level and structure of labor cost data for NUTS 1 regions. Both SES and LCS are conducted every four years.

To overcome the infrequent information on average wages at the sectoral level, we use the Labour Cost Index (LCI) to impute the levels of average hourly wage by economic activity at quarterly frequency. The quarterly LCI provides information on the short-term change in the total hourly costs for employers to maintain their employees, broken down by cost items and economic activity. As the labor cost index is measured in current prices in national currencies, we choose the average hourly wage data in the SES and merge it with the labor cost index data. We then conduct a simple regression of average hourly wage on the quarterly labor cost index of wages and salaries, controlling for country-sector fixed effects. We use the predicted wage levels of the regression as the average wage at quarterly frequency. Panel (a) of Figure 2 compares the predicted average hourly wage with the data in the SES (available for 2002, 2006, 2010, 2014, and 2018). It shows that the predicted wage levels are reasonably close to the actual data.

Similarly, to address the issue of limited wage data at the regional level, we turn to a related concept of compensation per employee by NUTS 2 regions, constructed from the national accounts data. Compensation usually includes more than wages. We conduct a simple regression of monthly wage on hourly compensation per employee, controlling for country-region fixed effects. We use the predicted wage levels as the average regional wage. Panel (b) of Figure 2 shows again that the the predicted wage levels match the actual data relatively well, though regional level survey data have much less observations than sector level survey data.

Figure 2. Average Wage by Sector and by Region: Survey Data vs. Imputation



(a) sectoral level **(b) regional level**

Sources: Eurostat and IMF staff calculations.

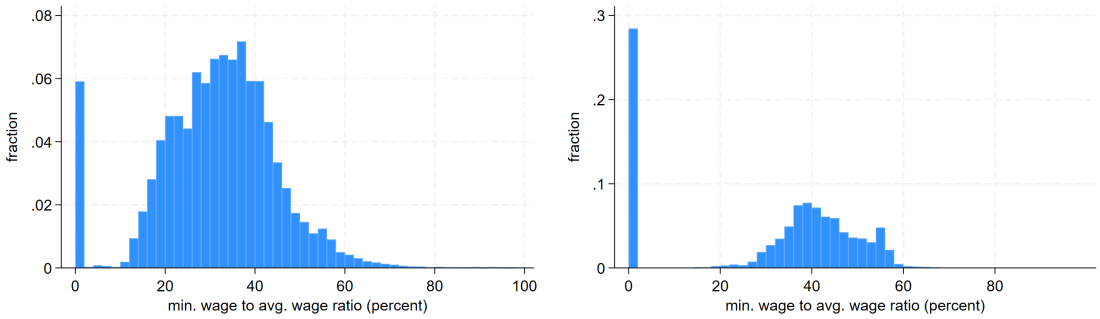
C. Minimum wage to average wage ratio

A key aspect of the treatment variable in equation (2) is the minimum wage to average wage ratio, commonly known as the Kaitz index (Dube and Lindner, 2024). Because of different average wages across sectors and regions, a single national minimum wage implies a different relative labor cost in each sector and in each region.

To make the monthly minimum wage comparable to the hourly average wage, we use the nominal national currency measure for both and apply a month-to-hour conversion rule that reflects the standard working hours by country. We explain more details in Appendix A.

Figure 3 presents the distribution of the minimum wage to average wage ratio across sectors between 2008-Q1 and 2024-Q2 and across regions between 2008 and 2022. There is a sizable mass at zero, which reflects that some countries do not have a minimum wage. The density at zero differs in panels (a) and (b) because of the difference in the availability of the imputed average wage at the sectoral level and at the regional level. The mode of the distribution for the non-zero part of the minimum wage to average wage ratio is similar in panels (a) and (b), both around 40 percent. This is reassuring since the imputation uses different data for sectors (SES and LCI) and regions (LCS and national accounts).

Figure 3. Distribution of the Minimum Wage to Wage Ratio Across Sectors and Regions



(a) across sectors **(b) across regions**

Sources: Eurostat and IMF staff calculations.

D. Labor Market Outcomes

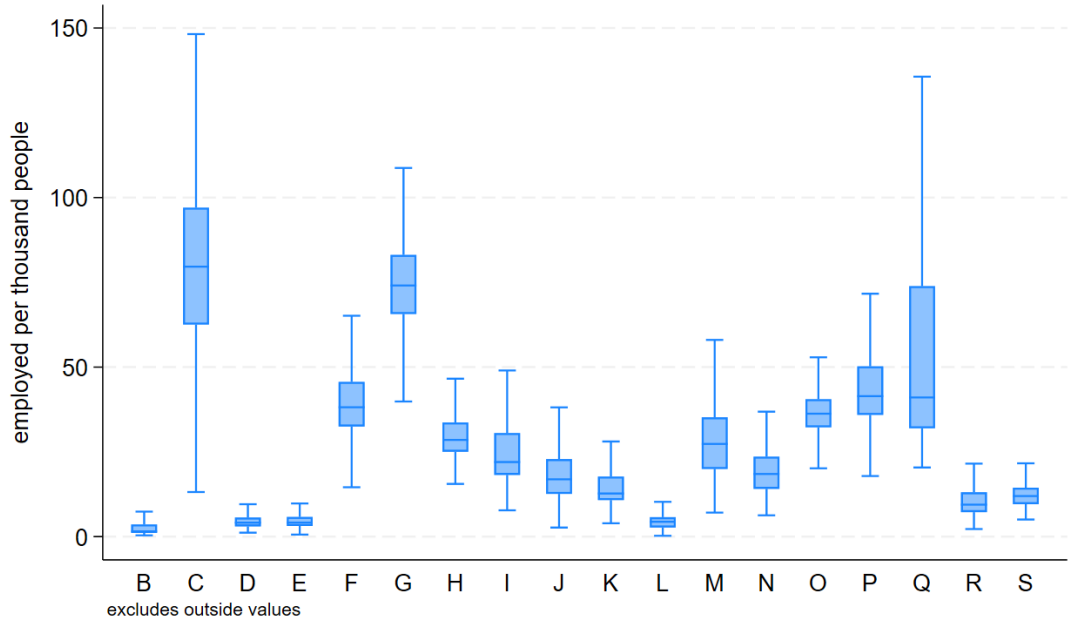
To gauge the impact of minimum wage increases on labor market outcomes, our primary focus is on employment. We consider total employment, employment by age and by sex. In principle, the ideal variable to use is employment rate, which accounts for population changes. However, while there is regional population data, there is no concept of population for a sector. As such, for regional analysis, we use the standard definition of employment rate, i.e., the ratio of the number of employed people to the size of the population in a region. For sectoral level analysis, we normalize employment by the relevant population[4] in the entire country. To examine different margins of employment adjustment, we also consider activity rate[5] and unemployment in our regional analysis.

The sectoral employment rate has large variations across sectors within countries and between countries. Figure 4 shows that, for example, the manufacturing sector (sector C) employs more than 100 per thousand people in Germany but just about 60 per thousand people in Spain. The information and communication sector (sector J), on the other hand, hires well below 50 per thousand people in all countries.

[4]For both regional and sectoral analyses, we use population aged 15+ as the denominator for the employment rate. However, our results do not depend on the age group of the normalizing population. This is because with country-specific time trends included, demographic changes are controlled for. We obtain identical results if we use the working-age population (aged 15-64) as the denominator.

[5]The activity rate as defined in Eurostat is synonymous to the labor force participation rate.

Figure 4. Distribution of Employment Rate by Sector in European Countries



Notes: This box plot presents the distribution of the sectoral employment rate, defined as the ratio of sectoral employment to total population in a country, in the sectoral panel dataset. The center line in each box represents the median of the employment rate. The bottom of each box represents the 25th percentile and the top of each box the 75th percentile. The bottom "whisker" below the box is equal to the 25th percentile minus 1.5 times the interquartile range and the upper "whisker" above the box is equal to the 75th percentile plus 1.5 times the interquartile range. Sector code is presented in Table 2.
Sources: Eurostat and IMF staff calculations.

Table 2. Statistical Classification of Economic Activities in the European Community

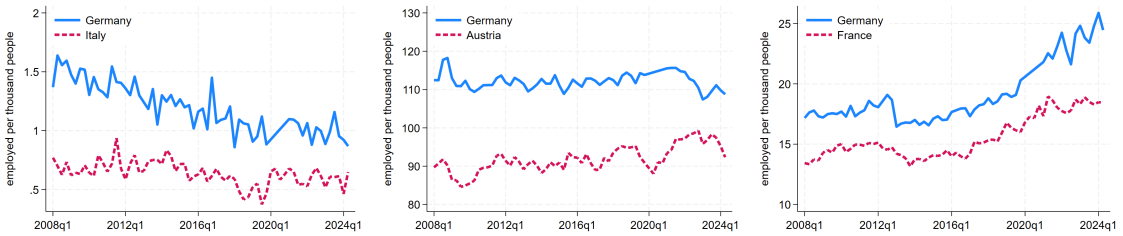
code	name
B	mining and quarrying
C	manufacturing
D	electricity, gas, steam and air conditioning supply
E	water supply, sewerage, waste management and remediation activities
F	construction
G	wholesale and retail trade; repair of motor vehicles and motorcycles
H	transportation and storage
I	accommodation and food service activities
J	information and communication
K	financial and insurance activities
L	real estate activities
M	professional, scientific and technical activities
N	administrative and support service activities
O	public administration and defense, compulsory social security
P	education
Q	human health and social work activities
R	arts, entertainment and recreation
S	other service activities

Source: Eurostat.

The sectoral employment rate at the quarterly frequency also displays strong seasonality and distinct levels across countries and sectors. Figure 5 presents a few examples. All panels show sizable seasonality. Panel (a) shows that Germany's employment in the mining and quarrying sector declines at a faster rate than Italy, albeit from a high level. Panel (b) shows that manufacturing employment is stable in Germany while rising moderately in Austria. Panel (c) shows that the information and communication sector employment is booming in both Germany and France, but to different degrees.

Taken together, the examples in Figures 4 and 5 suggest that it is important to account for country-specific trends and sector levels when analyzing the employment effects of minimum wage increases.

Figure 5. Sectoral Employment Rate Over Time



(a) mining and quarrying **(b) manufacturing** **(c) info. and com.**

Notes: This figure presents the sector employment rate, defined as the ratio of sectoral employment to total population in a country, for selected sectors and countries.
Sources: Eurostat and IMF staff calculations.

To reduce the influence of seasonality in our results, we smooth the employment rate using its four-quarter moving average:

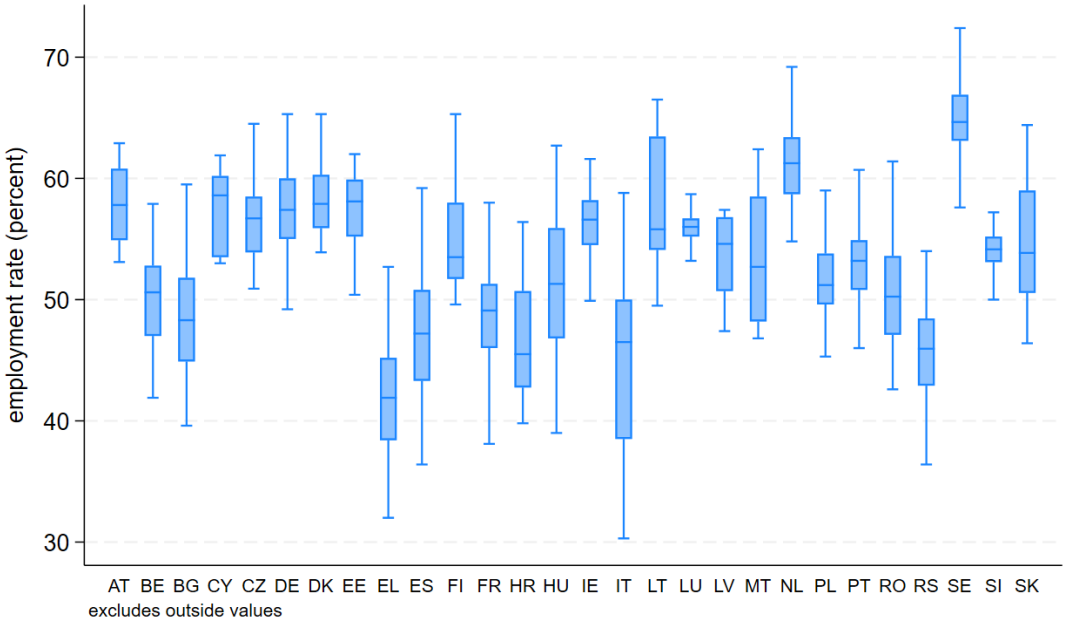
$$\text{employment rate at time } t = \frac{\sum_{k=0}^{3} \text{employment}_{t-k}}{\sum_{k=0}^{3} \text{population}_{t-k}} \tag{6}$$

Similar to the sectoral employment rate, the regional employment rate varies considerably within countries and between countries, as shown in Figure 6, but the variation across countries is smaller. Some countries, such as Greece (EL), have low employment rates in all regions; others, such as Sweden (SE), are the opposite. Italy (IT) stands out as having wide variations in regional employment rates.

Subnational regions in the same country tend to display similar employment trends over time. For example, Figure 7 shows that Stuttgart and Berlin both have increasing employment rates over the past decade, while Lombardia and Puglia in Italy both exhibit a U-shaped pattern.

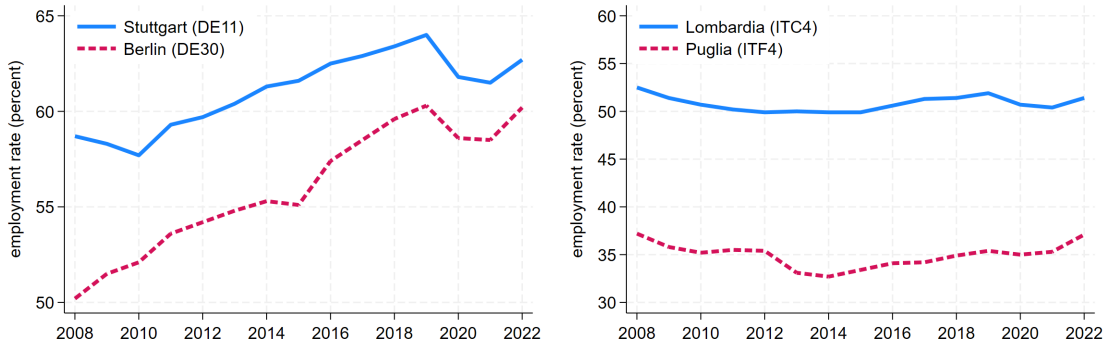
Figures 6 and 7 highlight the importance of controlling for country-specific trends and regional characteristics.

Figure 6. Distribution of Employment Rate by NUTS 2 Region



Notes: This box plot presents the distribution of the regional employment rate, defined as the ratio of the employment in a region to the population in the same region, in the regional panel dataset. The center line in each box represents the median of the employment rate. The bottom of each box represents the 25th percentile and the top of each box the 75th percentile. The bottom "whisker" below the box is equal to the 25th percentile minus 1.5 times the interquartile range and the upper "whisker" above the box is equal to the 75th percentile plus 1.5 times the interquartile range.
Sources: Eurostat and IMF staff calculations.

Figure 7. Regional Employment Rate Over Time



(a) Germany **(b) Italy**

Notes: This figure presents the regional employment rate, defined as the ratio of the employment in a region to the population in the same region, for selected regions.
Sources: Eurostat and IMF staff calculations.

Tables 3 and 4 present some summary statistics of labor market outcomes by population subgroup and by sector, respectively, in our sectoral panel dataset. At the sectoral level, female employment rates are lower than male employment rates on average, and young employment rates lower than the total employment rates. Employment rates have large variations across sectors. This is because each sector varies significantly in size yet they are all scaled by the same population by definition. For example, manufacturing (sector C) and retail (sector G) have the highest employment rates in our sample, as they are typically the largest sectors in the NACE Rev. 2 classifications for each country. To make the results interpretable, we use the logarithm of employment rates for the sectoral data for subsequent econometric analysis.

Table 5 presents the summary statistics of labor market outcomes in our regional panel dataset. At the regional level, both women and young population have lower employment rates, lower activity rates, and higher unemployment rates on average.

Table 3. Summary Statistics of Employment Rates in the Sectoral Panel Data

	Mean	Std	Min	p10	p25	p50	p75	p90	Max
employment rate									
(employed per thousand people)									
total	28.8	25.9	0.3	3.8	9.4	22.0	38.8	67.0	163.5
male	32.8	32.5	0.5	5.3	9.6	21.1	43.6	80.0	220.8
female	28.0	29.2	0.1	2.9	8.4	17.5	38.0	69.2	244.5
young (aged 15-24)	25.8	27.6	0.4	4.6	8.1	15.7	33.9	59.9	225.2
young male	32.9	31.8	0.6	5.4	11.2	22.0	45.3	74.5	224.4
young female	31.9	34.8	0.4	5.9	9.8	19.4	40.0	77.3	233.2

Notes: The sectoral employment rate is defined as the ratio of the employment in a sector to the respective population in the entire country, measured as the number of employed per thousand people. For example, the young female employment rate is the ratio of the number of the employed that are young and female to the population that is young and female. The employment rates are smoothed to remove seasonality as in equation (6).
Sources: Eurostat and IMF staff calculations.

Table 4. Employment Rates by Sector in the Sectoral Panel Data

	Mean	Std	Min	p10	p25	p50	p75	p90	Max
sector	employment rate (employed per thousand people)								
B	2.9	3.2	0.4	0.7	1.1	1.6	3.5	6.1	18.9
C	81.7	28.1	16.5	47.6	62.3	79.5	96.5	119.8	163.5
D	4.3	1.7	1.2	2.2	3.0	4.0	5.6	6.6	9.1
E	4.5	1.7	0.9	2.6	3.1	4.1	5.8	7.0	10.5
F	38.9	9.5	15.3	28.4	32.6	38.0	45.5	51.9	78.9
G	74.9	12.3	37.6	62.8	65.6	74.4	82.8	90.7	113.8
H	29.9	7.2	18.2	21.5	25.1	28.4	33.5	40.7	57.3
I	24.6	9.4	8.5	14.3	18.4	22.0	30.6	39.6	53.0
J	18.0	7.3	3.0	10.1	12.6	16.8	22.7	27.9	43.1
K	16.2	11.1	4.1	8.0	10.8	12.6	17.7	27.9	73.7
L	4.7	2.7	0.3	1.6	2.7	4.5	5.8	8.5	14.4
M	28.2	10.8	7.6	15.2	20.3	27.1	35.3	42.6	65.9
N	19.0	6.1	6.6	11.9	14.1	18.4	23.4	28.1	33.8
O	36.8	8.0	22.2	25.9	32.6	36.2	40.4	46.5	67.8
P	43.8	13.6	18.5	30.0	36.0	41.2	50.6	56.2	102.9
Q	54.0	28.7	20.8	26.6	32.1	40.8	73.3	92.6	148.2
R	10.5	5.0	2.5	5.9	7.3	9.4	13.1	15.0	36.0
S	12.1	3.2	5.2	7.9	9.6	11.9	14.4	16.5	22.8
Average	28.8	25.9	0.3	3.8	9.4	22.0	38.8	67.0	163.5

Notes: The sectoral employment rate is defined as the ratio of the employment in a sector to the respective population in the entire country, measured as the number of employed per thousand people.
Sources: Eurostat and IMF staff calculations.

Table 5. Summary Statistics of Labor Market Variables in the Regional Panel Data

	Mean	Std	Min	p10	p25	p50	p75	p90	Max
employment rate (percent)									
total	52.2	7.3	30.3	42.1	47.8	52.6	57.3	61.3	72.7
female	46.2	8.4	20.2	35.2	41.1	46.9	51.9	56.0	71.1
male	58.5	6.7	36.4	49.1	54.3	58.8	63.4	67.0	77.8
young (aged 15-24)	32.4	14.5	6.1	15.7	21.3	28.6	43.7	53.6	81.2
young female	30.5	15.4	4.1	13.7	18.4	26.1	42.8	52.2	83.1
young male	35.1	13.9	8.8	18.4	24.7	32.5	45.1	55.6	83.2
activity rate (percent)									
total	57.1	5.9	36.8	50.0	53.6	57.3	60.7	64.1	78.1
female	50.8	7.1	24.6	42.4	46.8	50.9	55.1	58.5	75.9
male	63.8	5.1	39.1	57.1	60.4	64.1	67.4	70.1	81.1
young (aged 15-24)	39.9	13.4	11.7	24.9	29.7	36.3	50.4	59.0	86.7
young female	36.9	14.7	10.0	21.0	25.2	32.9	48.5	57.1	88.4
young male	42.9	12.6	14.7	28.2	33.5	40.2	52.1	61.2	88.4
unemployment rate (percent)									
total	8.9	6.0	1.2	3.3	4.7	7.3	11.0	17.4	37.0
female	9.7	7.0	1.4	3.3	4.9	7.6	11.7	19.9	48.0
male	8.6	5.4	0.8	3.2	4.7	7.3	10.7	16.5	34.8
young (aged 15-24)	23.2	13.7	2.8	8.3	12.2	20.5	30.4	44.3	79.2
young female	26.4	15.4	3.2	9.6	14.3	23.0	34.3	50.0	90.7
young male	24.0	13.0	3.5	9.7	14.1	21.2	30.4	43.4	82.4

Notes: The regional employment rate is defined as the ratio of the employment in a region to the population in the same region, measured in percent. The activity rate is the ratio of the labor force to the population. The unemployment rate is the ratio of the unemployed to the labor force.
Sources: Eurostat and IMF staff calculations.

IV. EMPIRICAL FINDINGS

A. Dynamic Impact on Employment Rates

In this section, we present results of the local projections method on the employment impact of minimum wage increases. Our main variable of interest is the coefficient τ^h in equation (1), which is the treatment effect at horizon h.

As mentioned before, we consider both the employment effects at the sectoral level and the regional level. The sectoral level data has more variations in the minimum wage to average ratio, while the regional level data has activity rates and unemployment rates that further shed lights on the margins of adjustment following minimum wage increases. We also consider minimum wage increases as a continuous variable as in equation (2) and large minimum wage increases as a dummy variable as in equation (3).

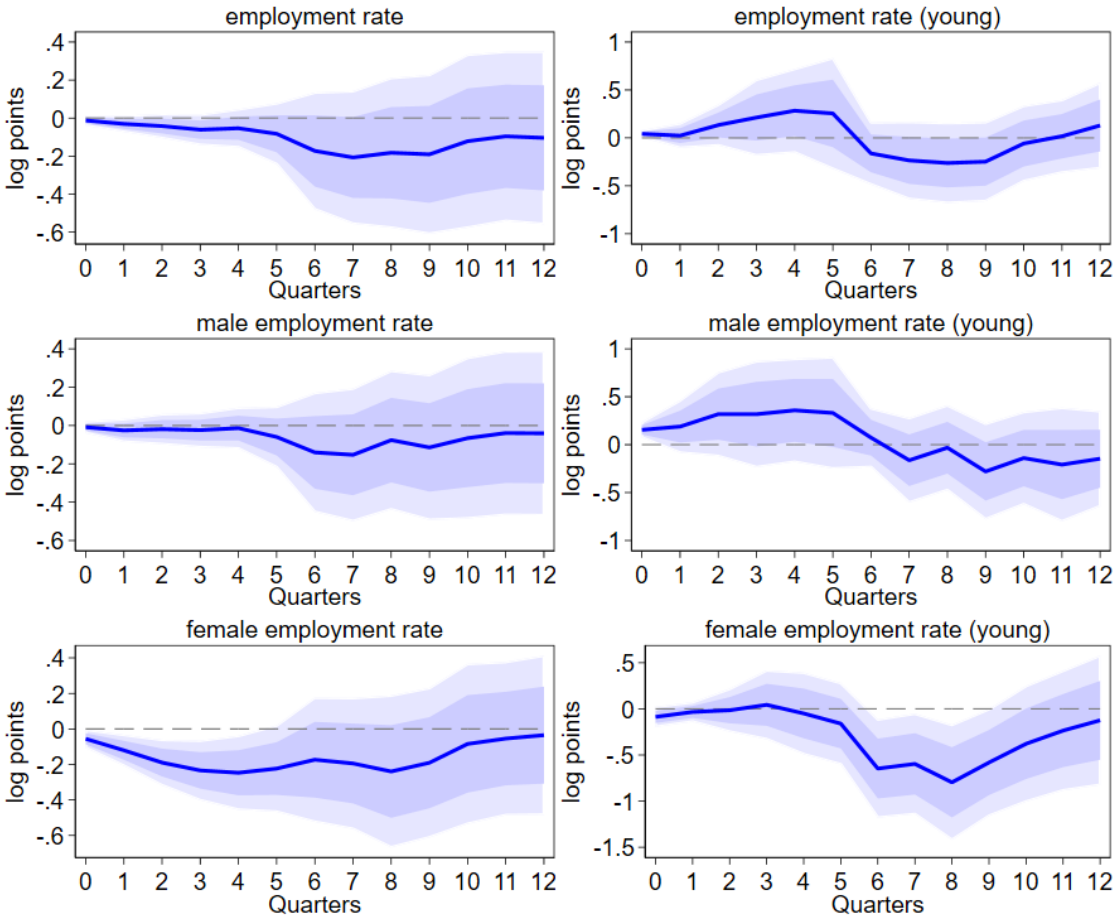
1. Sectoral Level Impact

At the sectoral level, we measure the employment rate by dividing the number of employed in a sector by the total population in a country. Changes in the logarithm of the employment rate therefore reflect the percent increase of the sectoral employment on top of population changes. The sectoral employment data are of quarterly frequency that allows for the examination of the short-to-medium-term dynamics.

Figure 8 presents the results when the treatment variable is continuous. In the top left chart, the point estimates show that the overall employment impact of minimum wage increases is almost zero in the first four quarters, but becomes negative afterwards.

The overall impact masks some heterogeneity across gender and age groups. The impact on female employment is negative in the first five quarters, as shown in the bottom left chart. The impact on young employment, mostly for young men, is positive in the first few quarters. This suggests that minimum wage increase could incentivize young males to look for jobs—or take on part-time jobs, resulting in a positive employment effect, while discouraging older population, particularly women, from working.

Figure 8. Sectoral Employment Effects of Minimum Wage Changes



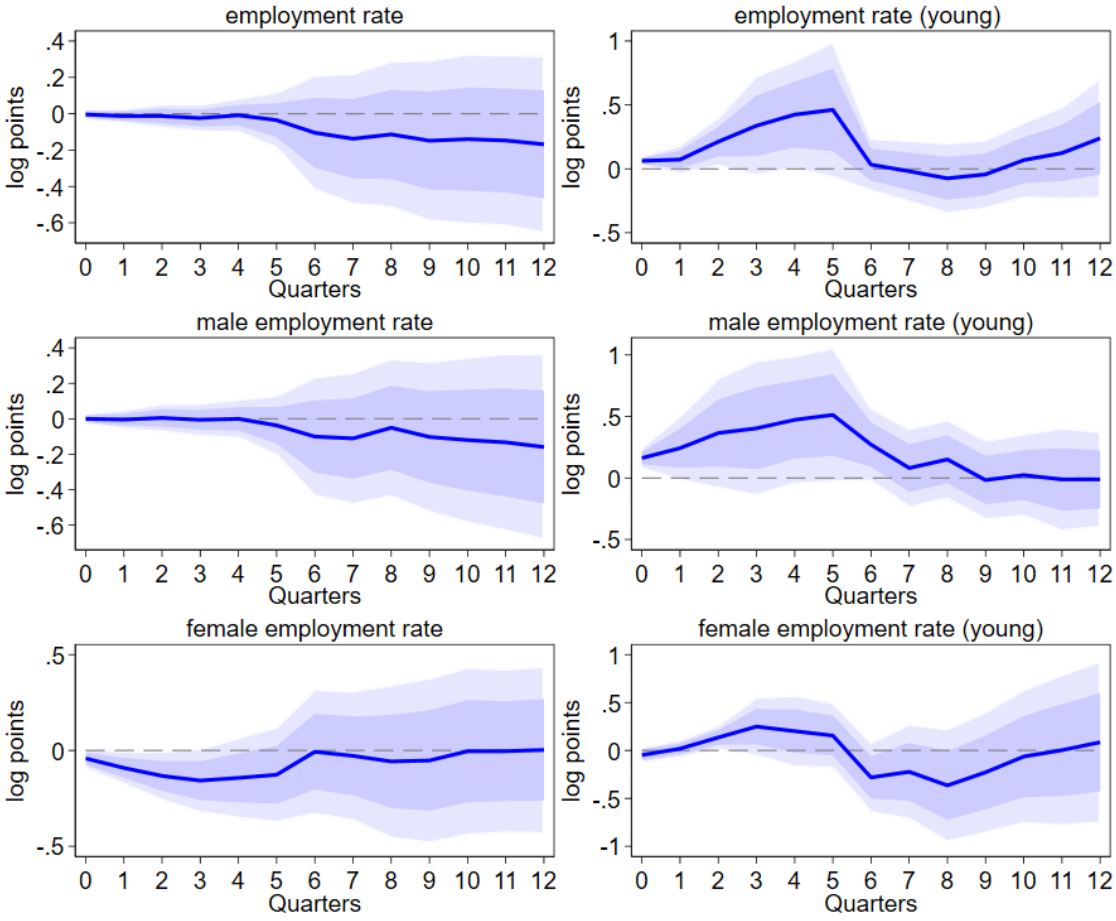
Notes: This figure presents results of the local projections of sectoral employment rates on minimum wage changes, controlling for lags, country-specific time trends, and country-industry fixed effects as in equation (1), for the entire and sub population groups. The sectoral employment rate is measured as the logarithm of the ratio of the employment in a sector to the respective population in the country. Minimum wage changes are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figures 9 and 10 examine the impact of positive and negative minimum wage changes, respectively. Recall that positive minimum wage changes are those in which the minimum wage increases more than inflation. Figure 9 shows that in the short term, the impact on the average employment rate is close to zero while the impact on the female employment rate is slightly negative. For the young, however, positive minimum wage changes appear to boost their employment in the short term. Negative minimum wage changes are those in which the minimum wage does not increase or increase less by inflation. Figure 9 shows that their impact manifests in the medium to long term. Notably, negative minimum wage changes raise female employment rates, in particular young female employment rates.

Why does the impact of positive minimum wage changes concentrate in the short term while that of negative minimum wage changes concentrate in the medium term? Intu-

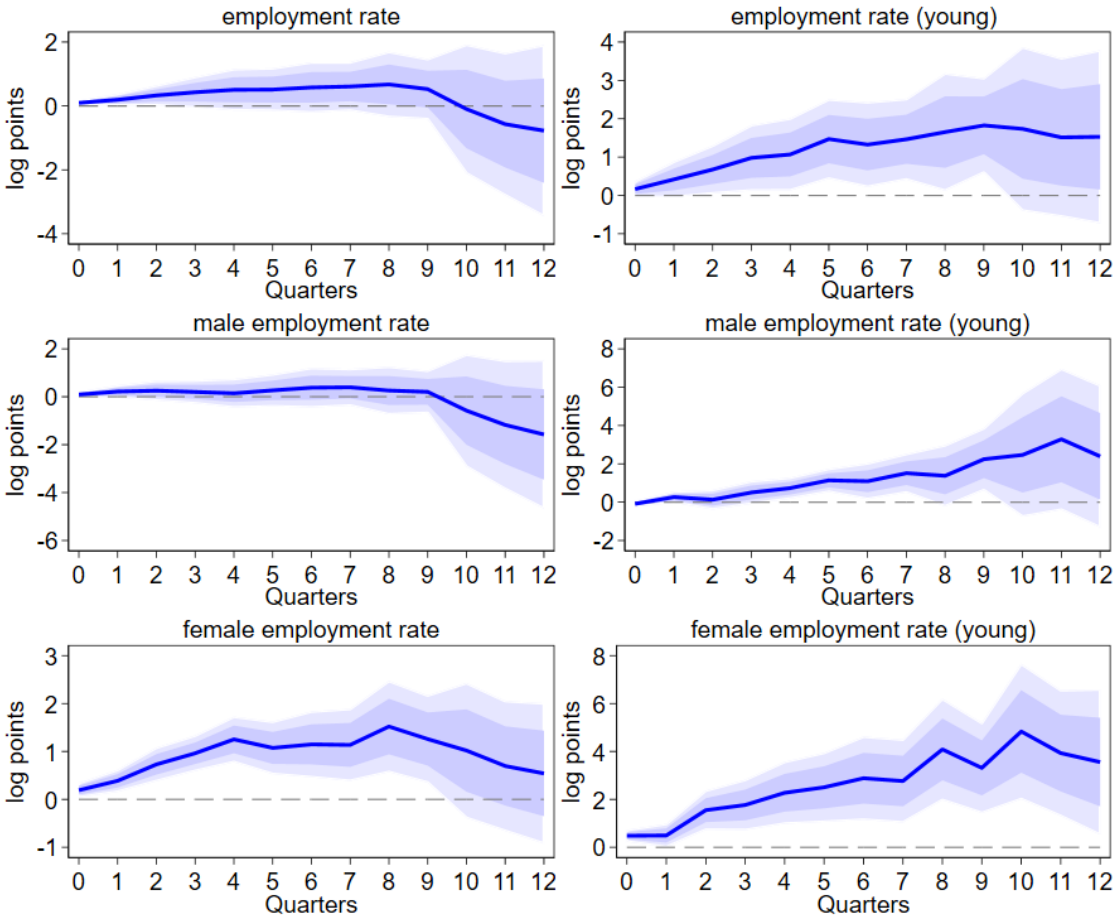
itively, an increase in the real minimum wage could be immediately binding for some firms in the economy, raising their labor cost and forcing them to adjust employment in the short term. In contrast, a decrease in the real minimum wage occurs slowly with inflation. Firms only respond to such easing of the real labor cost in the medium term.

Figure 9. Sectoral Employment Effects of Real Positive Minimum Wage Changes



Notes: This figure presents results of the local projections of sectoral employment rates on real positive minimum wage changes, controlling for lags, country-specific time trends, and country-industry fixed effects as in equation (1), for the entire and sub population groups. The sectoral employment rate is measured as the logarithm of the ratio of the employment in a sector to the respective population in the country. Minimum wage changes are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 10. Sectoral Employment Effects of Real Negative Minimum Wage Changes

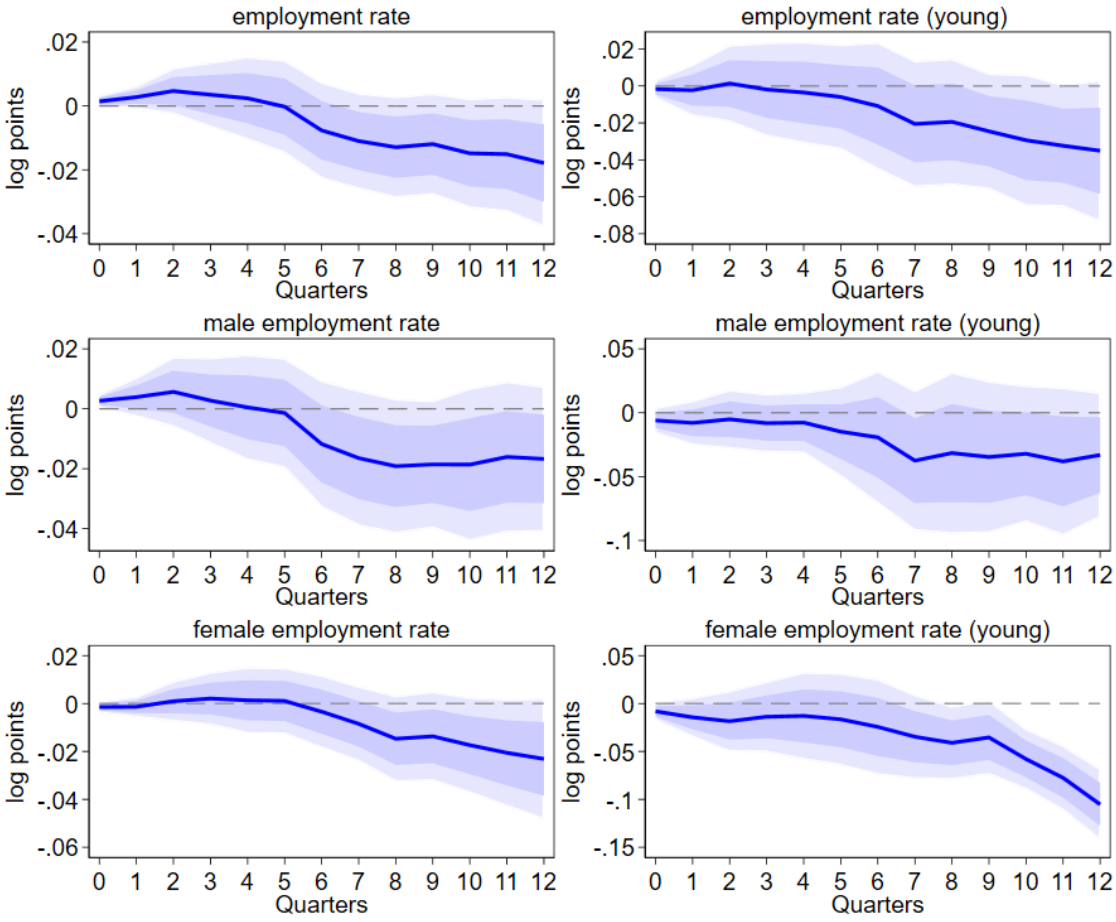


Notes: This figure presents results of the local projections of sectoral employment rates on real negative minimum wage changes, controlling for lags, past minimum wage to average wage ratios, country-specific time trends, and country-industry fixed effects as in equation (1), for the entire and sub population groups. The sectoral employment rate is measured as the logarithm of the ratio of the employment in a sector to the respective population in the country. Minimum wage changes are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 11 shows the results of large minimum wage increases, where the treatment variable is discrete. Notably, the employment impact is universally negative after five or six months. The negative impact is stronger for the young, and particularly young women, in the medium term.

The different results for female employment in Figures 8 and 11 suggest that the impact of minimum wage increases could be nonlinear in its size. While small increases might reduce female employment, large increases could have the opposite impact.

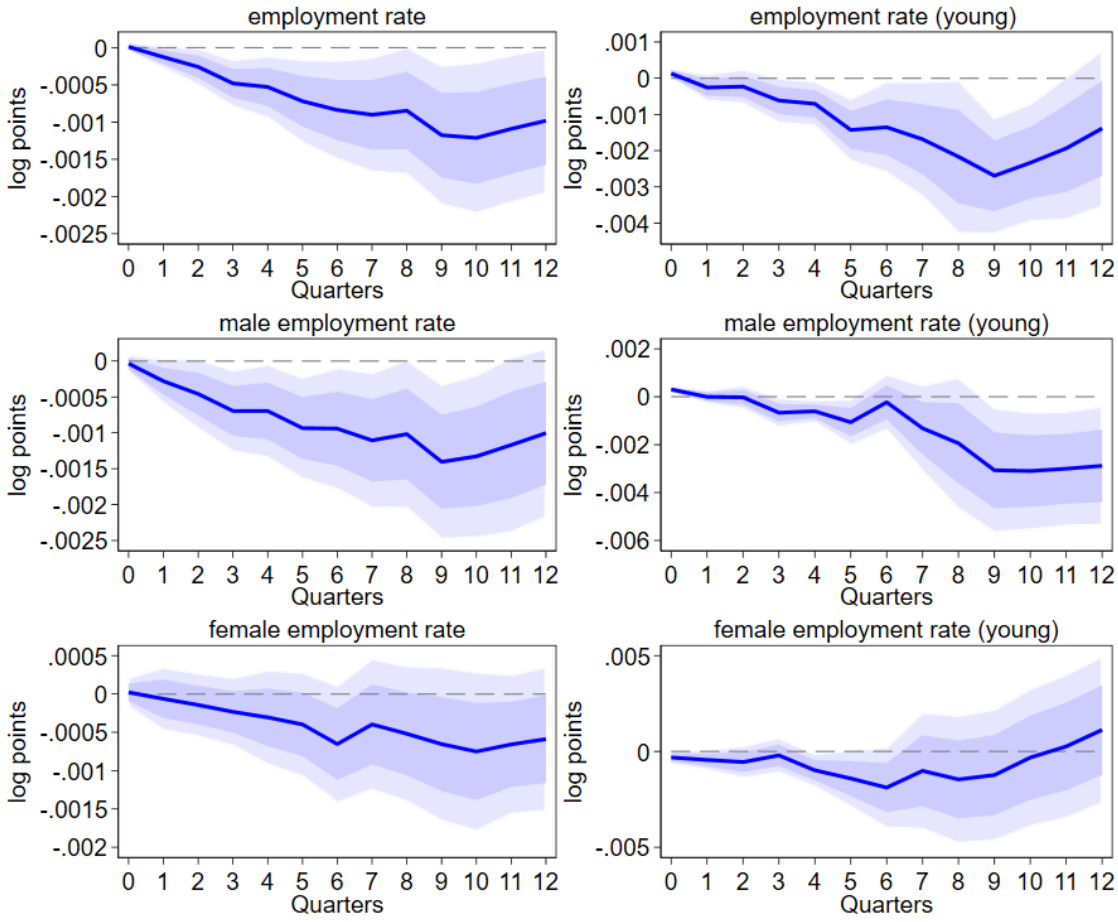
Figure 11. Sectoral Employment Effects of Large Minimum Wage Increases



Notes: This figure presents results of the local projections of sectoral employment rates on large minimum wage increases, controlling for lags, country-specific time trends, and country-industry fixed effects as in equation (1), for the entire and sub population groups. The sectoral employment rate is measured as the logarithm of the ratio of the employment in a sector to the respective population in the country. Large minimum wage increases are discrete and relative and past average wages, representing relative minimum wage increases exceeding the 90th percentile in the sample as in equation (3). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 12 explores the dependence of employment impact on the previous minimum wage to average ratios. There we add an interaction term $w_{c,i,t} \times \frac{MW_{t-1}}{W_{c,i,t-1}}$ to equation (2) and plot the coefficient before it. The coefficient is negative across sub-population groups, and becomes more negative at longer horizons. This suggests that if the minimum wage to average is already high, a further increase in the minimum wage would have a more negative impact on employment, which manifests over time.

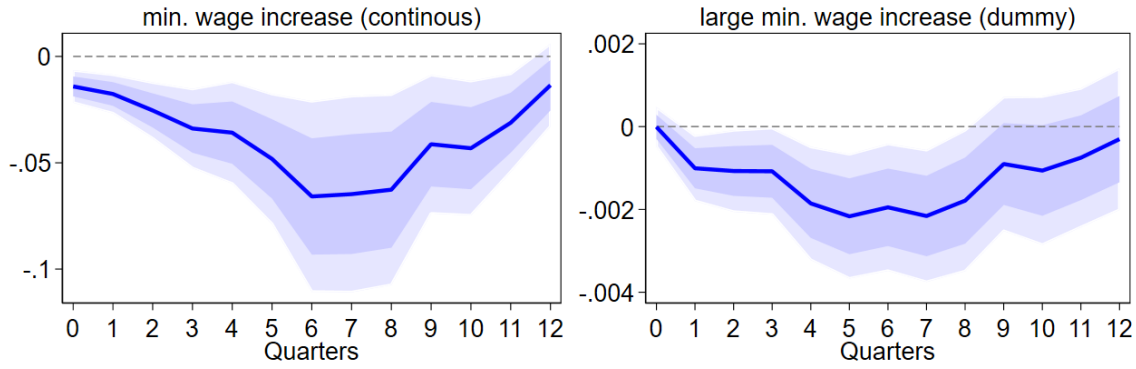
Figure 12. Sectoral Employment Effects of Large Minimum Wage Increases: The Role of Minimum Wage to Average Wage Ratio



Notes: This figure presents results of the local projections of sectoral employment rates on the interaction between minimum wage increases and minimum wage to average wage ratios, i.e., the coefficients before the interaction term $w_{c,i,t} \times \frac{MW_{t-1}}{W_{c,i,t-1}}$ added to equation (2) , controlling for lags, country-specific time trends, and country-industry fixed effects, for the entire and sub population groups. The sectoral employment rate is measured as the logarithm of the ratio of the employment in a sector to the respective population in the country. Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 13 considers the impact on hours worked. The impact is negative for both the continuous minimum wage increase and the discrete large minimum wage increase. This is interesting as it points out that even if employment remains unchanged, firms might reduce employees' working hours in response to minimum wage increases to contain the labor cost.

Figure 13. Sectoral Effects on Hours Worked of Minimum Wage Changes



Notes: This figure presents results of the local projections of sectoral hours worked on minimum wage increases, controlling for lags, past minimum wage to average wage ratios, country-specific time trends, and country-industry fixed effects as in equation (1), for the entire and sub population groups. The hours worked is measured as the logarithm of the ratio of the actual average hours worked to the usual hours worked in a sector. Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64-standard deviation confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

2. Regional Level Impact

At the regional level, the employment rate is defined as the ratio of the regional employment over the regional population. Its change is measured by percentage points. Similarly, the activity rate is defined as the ratio of the regional labor force over the regional population, while the unemployment rate is defined as the ratio of the unemployed over the regional labor force. Their relationship follows:

$$\text{employment rate} = \text{activity rate} \times (1 - \text{unemployment rate}).$$

Regional activity rates and unemployment rates therefore provide insights into different margins of adjustment of employment effects of minimum wage increases. Note that the regional level data are of annual frequency and the employment effects are examined over the medium term.

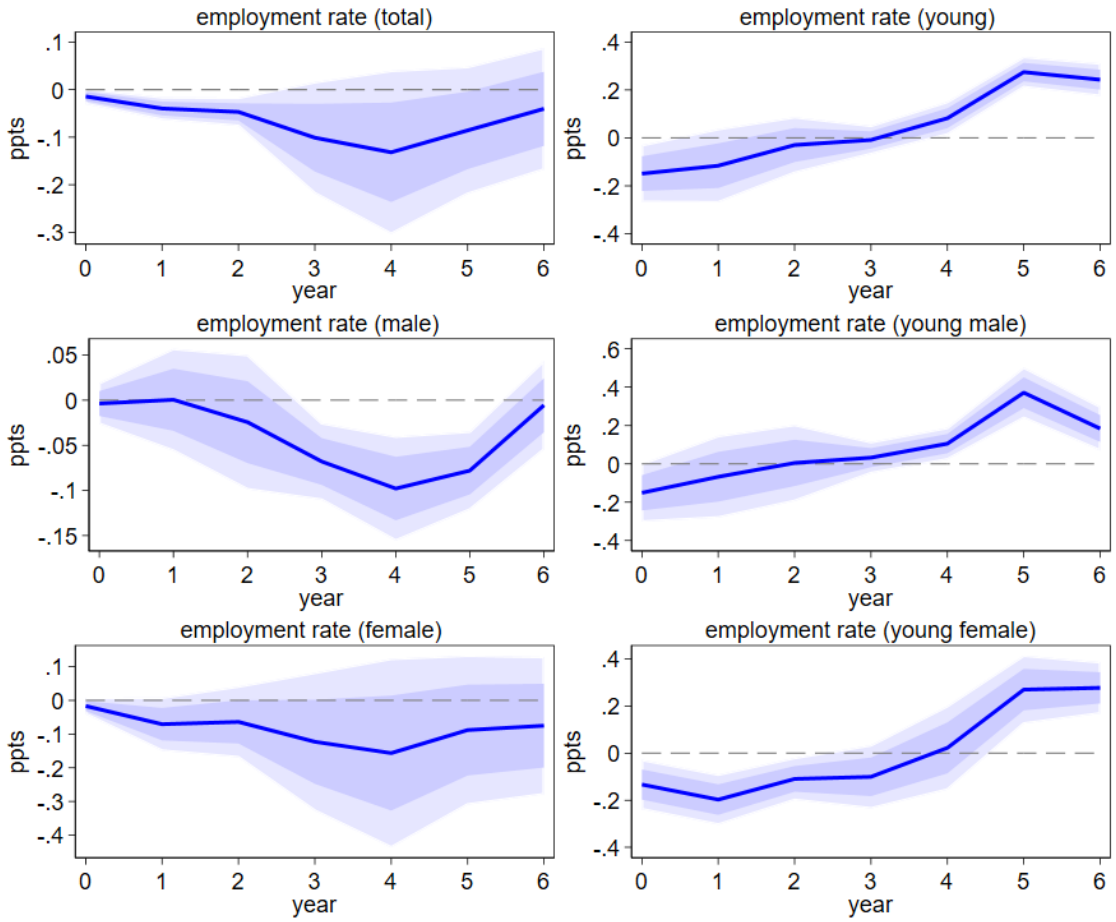
Figure 14 shows that over the medium term, the overall employment effect of minimum wage increases at the regional level is negative, with the negative impact peaking in the fourth year. Both male and female employment rates decline by about 0.1 percentage points, though the impact on male employment is more precisely estimated. To put things in perspective, for a region of one million population, a 10 percent minimum wage increase implies a decline of employment of $10 \times 0.1\text{ppts} \times 1\text{million} = 10,000$ people, a nontrivial amount of population. Different from the sectoral level results, the regional level results point to negative employment effects for the young in the near term and positive effects in the medium term.

Figures 15 and 16 show that the employment effect of minimum wage increases at the regional level is driven by labor participation. As minimum wage increases, activity rates decline and mirror the patterns of employment rates, while unemployment rate changes remain statistically not different from zero. The employment effect is larger for the young and particularly young women.

Why do the employment effects on the young population at the sectoral level and at the regional level display different patterns? First, employment dynamics at the sectoral level and at the regional level do not have to be the same. In a given region, a high minimum wage relative to the average wage in a certain industry could incentivize young people to work in that industry. From a sectoral perspective, a high minimum wage to the average wage ratio boosts employment for the young in the short term. However, this does not contradict the fact that the minimum wage could be prohibitively high compared to the average wage for the region. In the short term, it is possible that some firms employ young people informally so as to avoid the binding minimum wage, but in the medium to long term, such employment is formalized, resulting in a decline in activity rates in the short term and an increase in the medium term.

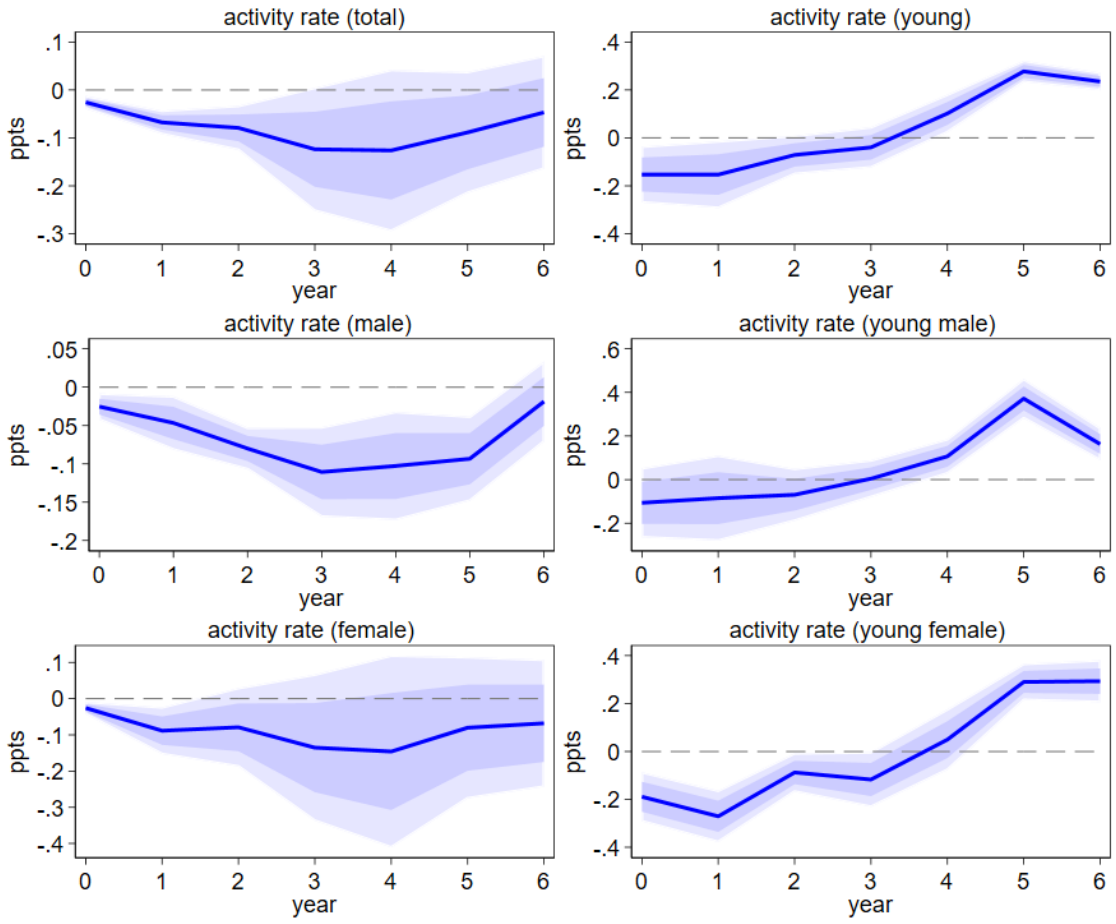
Second, migration might also play a role. A national minimum wage increase could compress the difference between the minimum wage and the average wage, incentivizing skilled young people to migrate to richer regions. Figure 17 presents some evidence on this front using the net migration rate (immigrants minus emigrants). Following a minimum wage increase, the net migration rate declines first before rebounding in the medium term. As a result of migration, low-income regions could see activity rates decline, while high-income regions see activity rates increase. Since the same national minimum wage increase implies larger minimum wage increases for lower-income regions, reflected in Figure 15, regions with a higher minimum wage increase relative to average wage experience more decline in activity rates, and hence more decline in employment rates.

Figure 14. Regional Effects on Employment Rates of Minimum Wage Changes



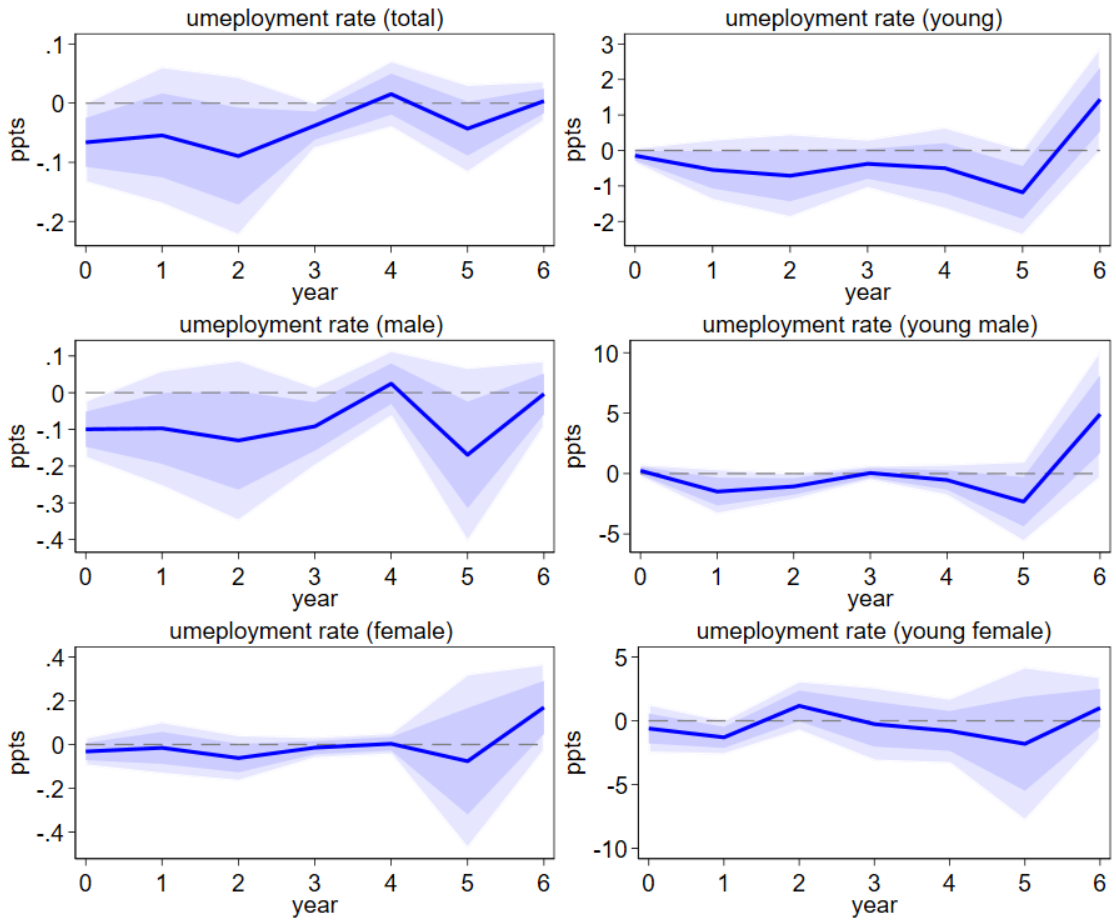
Notes: This figure presents results of the local projections of regional employment rates on minimum wage increases, controlling for lags, country-specific time trends, and NUTS 2 region fixed effects as in equation (1), for the entire and sub population groups. The regional employment rate is measured as the ratio of the employment in a region to the region's population . Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 15. Regional Effects on Activity Rates of Minimum Wage Changes



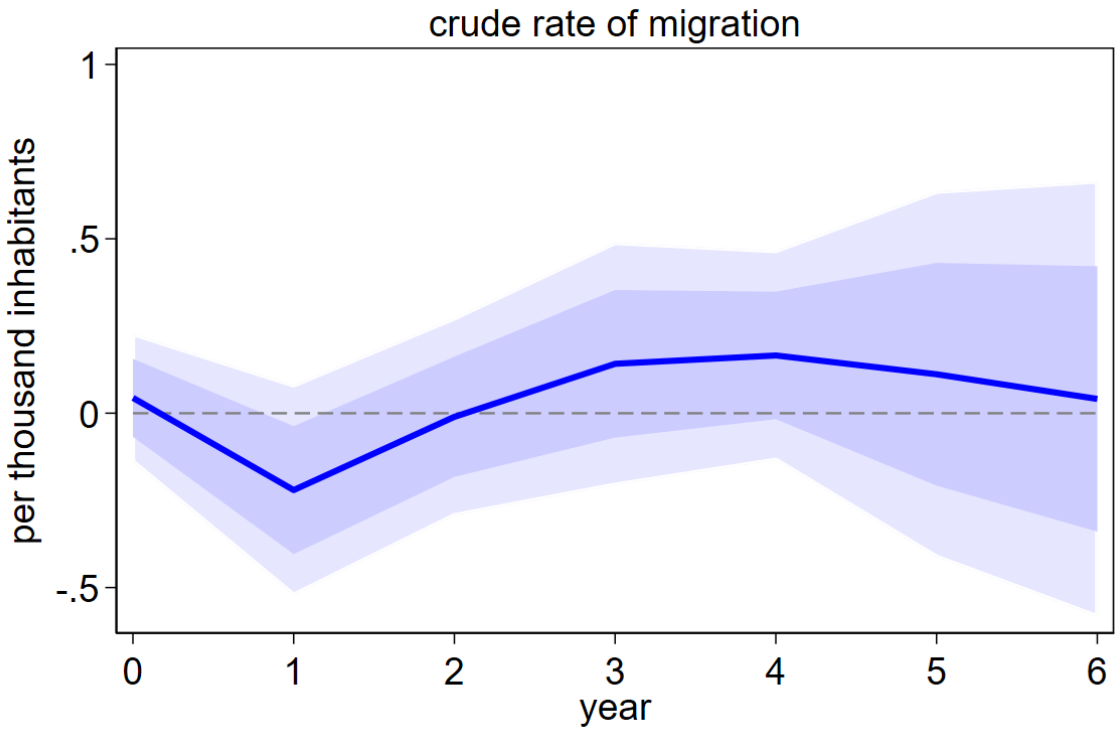
Notes: This figure presents results of the local projections of regional activity rates on minimum wage changes, controlling for lags, country-specific time trends, and NUTS 2 region fixed effects as in equation (1), for the entire and sub population groups. The regional activity rate is measured as the ratio of the labor force in a region to the region's population . Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 16. Regional Effects on Unemployment Rates of Minimum Wage Changes



Notes: This figure presents results of the local projections of regional unemployment rates on minimum wage changes, controlling for lags, country-specific time trends, and NUTS 2 region fixed effects as in equation (1), for the entire and sub population groups. The regional unemployment rate is measured as the ratio of the unemployed in a region to the region's labor force . Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Figure 17. Regional Effects on Net Migration of Minimum Wage Changes



Notes: This figure presents results of the local projections of net migration rates on minimum wage changes, controlling for lags, country-specific time trends, and NUTS 2 region fixed effects as in equation (1). The net migration rate is measured as the number of net migrants (immigrants minus emigrants) per thousand inhabitants. Minimum wage increases are continuous and relative and past average wages, as in equation (2). Shaded areas are 1- and 1.64- standard deviation pointwise confidence bands using robust standard errors clustered at the country level.
Sources: Eurostat and IMF staff calculations.

Both the sectoral and the regional level results show that an increase in the minimum wage relative to the average wage tends to reduce employment in the medium term, with stronger impact for certain females and young population. As females and the young in general earn less, this suggests that the minimum wage to average ratio is a crucial aspect of heterogeneity for the employment effects. In the next section, we explore such heterogeneity using generalized random forests.

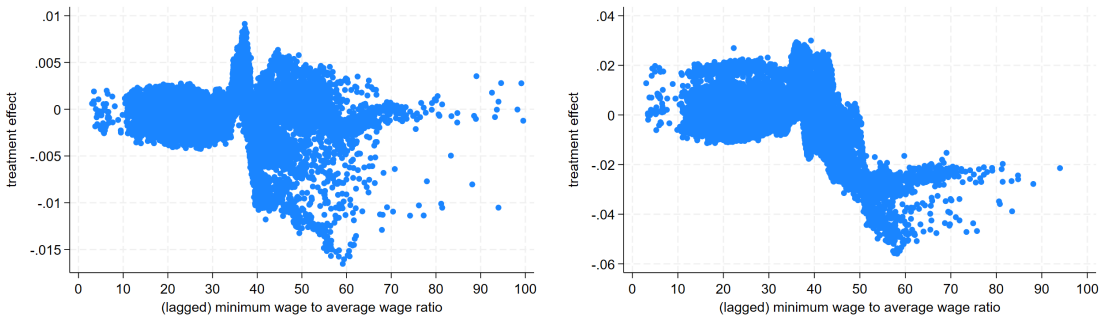
B. Heterogeneity

In this section, we present the results of generalized random forests as in equation (5). We focus on the heterogeneity of the impact of minimum wage increases across various minimum wage to average wage ratios both in the short term and the long term.

Figure 18 contrasts the treatment effects against the minimum wage to average wage ratios at the sectoral level. Each dot represents a country-sector-quarter observation at the

time of a large minimum wage increase. In the short term, large minimum wage increases have little impact on employment when the minimum wage to average ratio is below 35 percent prior to the increases. As the minimum wage to average ratio surpasses 35 percent, large minimum wage increases initially provide a boost to employment. As the ratio becomes larger, increasingly more egative impact on employment starts to appear. In the long term, the impact is more clear cut than that in the short term. When the minimum wage to average ratio is above 35 percent, large minimum wage increases tend to reduce employment.

Figure 18. Heterogeneous Treatment Effects on Sectoral Employment



(a) short term **(b) long term**

Notes: This figure presents results of the generalized random forests as in equation (4) at the sectoral level. Short-term refers to 1-quarter changes, while long-term refers to 12-quarter changes. Each dot represents an estimate of the treatment effect at the observational level.
Sources: Eurostat and IMF staff calculations.

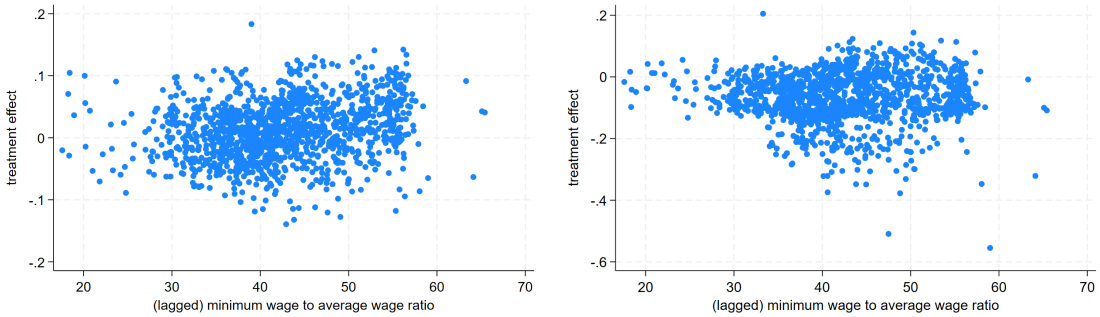
Figures 19, 20, and 21 show the heterogeneous treatment effects on employment rates, activity rates, and unemployment rates, respectively, at the regional level.

In the short term, employment rates increase slightly with the minimum wage to the average wage ratio. This is driven by the moderate increase in activity rates and partially offset by the increase in unemployment rates.

In the long term, the regional employment effects are mostly negative. There is no clear threshold where the regional employment effects change directions. The employment effects are concentrated around zero when the minimum wage to average wage ratio is below 35 percent. However, as the ratio rises above 40 percent, more regions experience negative employment effects. As in the short term, such pattern is primarily driven by the impact on activity rates. At low minimum wage to average wage ratios, a large minimum wage increase tends to boost activity rates moderately, driving up employment rates. At

high minimum wage to average wage ratios, a large minimum wage increase reduces activity rates—possibly due to its impact on informality—and reduces employment rates.

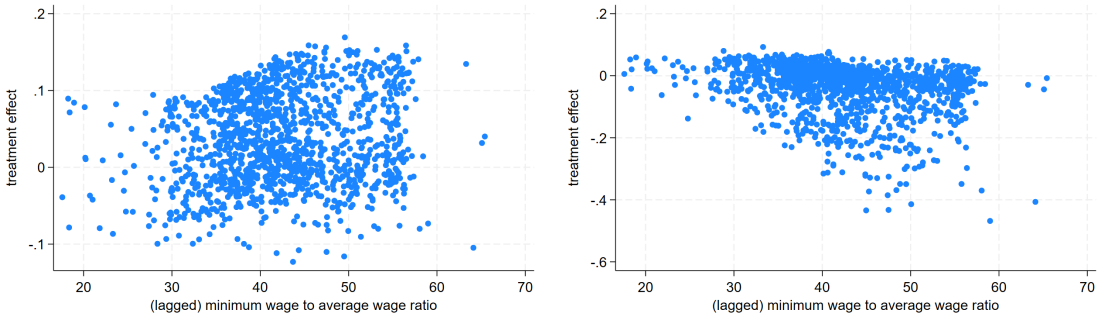
Figure 19. Heterogeneous Treatment Effects on Regional Employment Rates



(a) short term **(b) long term**

Notes: This figure presents results of the generalized random forests as in equation (4) at the regional level. Short-term refers to 1-year changes, while long-term refers to 3-year changes. Each dot represents an estimate of the treatment effect at the observational level.
Sources: Eurostat and IMF staff calculations.

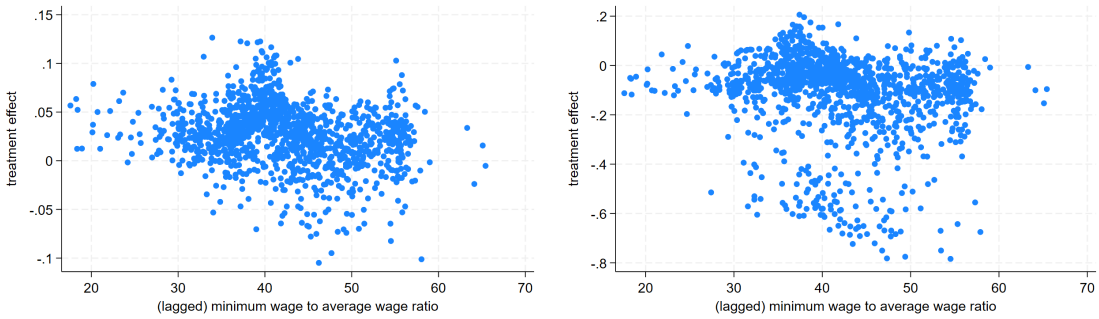
Figure 20. Heterogeneous Treatment Effects on Regional Activity Rates



(a) short term **(b) long term**

Notes: This figure presents results of the generalized random forests as in equation (4) at the regional level. Short-term refers to 1-year changes, while long-term refers to 3-year changes. Each dot represents an estimate of the treatment effect at the observational level.
Sources: Eurostat and IMF staff calculations.

Figure 21. Heterogeneous Treatment Effects on Regional Unemployment Rates



(a) short term **(b) long term**

Notes: This figure presents results of the generalized random forests as in equation (4) at the regional level. Short-term refers to 1-year changes, while long-term refers to 3-year changes. Each dot represents an estimate of the treatment effect at the observational level.
Sources: Eurostat and IMF staff calculations.

C. Policy implications

The sectoral and regional analysis shows that the overall employment effect of minimum wage increases is close to zero in the short term and negative in the medium term. However, the employment effect differs across sub-population groups and can exhibit opposite directions. The employment effect depends crucially on the minimum wage to average wage ratio, which indicates the degree of bindingness of the minimum wage. At low minimum wage to average wage ratios, a large minimum wage increase has little employment effects in the short term but positive effects in the long term. When the minimum wage to average wage ratio is above 35 percent of the sectoral average wage, the employment effects start to turn negative.

While a single national minimum wage has its merits and could reduce wage inequality and bring about increased allocation efficiency of workers (Dustmann and others, 2022), given the heterogeneous employment effects of the minimum wage increases, some meaningful differentiation of the minimum wage across sub-population groups, sectors, and regions, might be desirable, though not always politically palatable. Most European countries have a single national minimum wage, but large economies such as the United States, China, and India have regional minimum wages.

Using the minimum wage as a poverty reduction policy should be carefully considered. Minimum wage only affects the wages of those who are formally employed and at the lower end of the wage distribution. While an increase in the minimum wage contributes to reducing in-work poverty, its effect on those without formal employment is unclear. Our sectoral results suggest that a threshold effect of the minimum wage on employment.

If the minimum wage is already high, further increase could even counteract poverty reduction.[6] Furthermore, as our regional results point out, minimum wage increases affect both activity rates and unemployment rates. A high minimum wage could push people out of the labor force. Recent work by Burkhauser, McNichols, and Sabia (2025) shows that minimum wage increases could even lead to a slight increase in the poverty rate. While an important part of broader poverty reduction efforts, minimum wage policies alone cannot address poverty. Targeted income policies with no adverse employment effects, such as Earned Income Tax Credit in the United States, should also be considered. Active labor market policies—including targeted short-term training programs—could help detached (and employed) lower-skilled workers build the skills required for new fast-growing occupations (Duval and others, 2022).

V. Conclusion

In this paper, we examine the dynamic and heterogeneous employment effects of minimum wage increases across sectors and regions in European countries. By exploiting variations in minimum wage to average wage ratios and using two complementary empirical approaches, local projections and generalized random forests, we provide nuanced insights into how minimum wage policies interact with labor market structures. Our analysis yields three key findings.

First, the average employment effects of minimum wage increases are negligible in the short term (about one year) but turn negative in the medium to long term. At the sectoral level, employment rates decline after one year. Regionally, the negative effects peak in the third or fourth year, with a 10 percent minimum wage increase reducing employment by approximately 0.1 percentage points, which is equivalent to 10,000 jobs in a region of one million people.

Second, the effects are highly heterogeneous. Sectoral results reveal that young workers, mostly young men, experience short-term employment gains following minimum wage increases, despite near zero employment gains for the population on average. While positive real minimum wage changes tend to boost the employment rate for the young in the short term, negative real minimum wage changes tend to boost it in the medium term. At the regional level, activity rate declines drive employment losses following minimum wage increases. For the young, there is a rebound in the employment rate in the medium term.

[6] Recent international studies also point to temporary and diminishing effects of minimum wage increases on poverty reduction. See, for example, Campos-Vazquez and Esquivel (2023); Sotomayor (2021).

Third, generalized random forests identify threshold effects: employment effects turn negative when the minimum wage exceeds 35 percent of the sectoral average wage. The threshold highlights the importance of the minimum wage's "bindingness" in shaping labor market outcomes.

Other margins of adjustments might also respond to minimum wage changes in addition to the employment rate. At the sectoral level, the adjustments could occur through hours worked despite stable headcounts, while at the regional level, informality and migration might play a role. This underscores the multidimensional nature of employment responses to wage policies.

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APPENDIX A. MORE DETAILS ABOUT MINIMUM WAGE

A.1. Tables

Table 6. Minimum Wage Month-to-hour Conversion Rule

country code	standard weekly working hours	month-to-hour conversion factor
12-month minimum wage		
BE	38	164.7
BG	40	173.3
CY	40	173.3
CZ	40	173.3
DE	38.1	165.5
EE	40	173.3
FR	35	151.7
HR	40	173.3
HU	40	173.3
IE	39	169.0
LT	40	173.3
LU		173.0
LV	40	173.3
MT	40	173.3
NL	36	156.0
PL	40	173.3
RO	40	168.0
RS	40	174
SI	40	173.3
SK	40	173.3
TR	45	195.0
14-month minimum wage		
EL	40	173.3
ES	40	173.3
PT	40	173.3
no minimum wage		
AT, DK, FI, IS, IT, NO, SE		

Notes: The monthly minimum wage is converted to an hourly rate by applying country-specific conversion rules. Generally, the standard factor is calculated by multiplying standard weekly working hours by 52 weeks and dividing by 12 months. However, variations exist based on national practices as reported by Eurostat. In Germany, the conversion is based on multiplying standard weekly hours by 4.345 weeks per month. In Luxembourg, the hourly minimum wage is set as 1/173 of the monthly rate, while in Romania, it is set as 1/168 of the monthly rate. Serbia uses a conversion factor based on 52.2 weeks annually rather than the standard 52 weeks.

PUBLICATIONS